Indian Institute of Science

Design of Photovoltaic Systems

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NPTEL Online Certification Course

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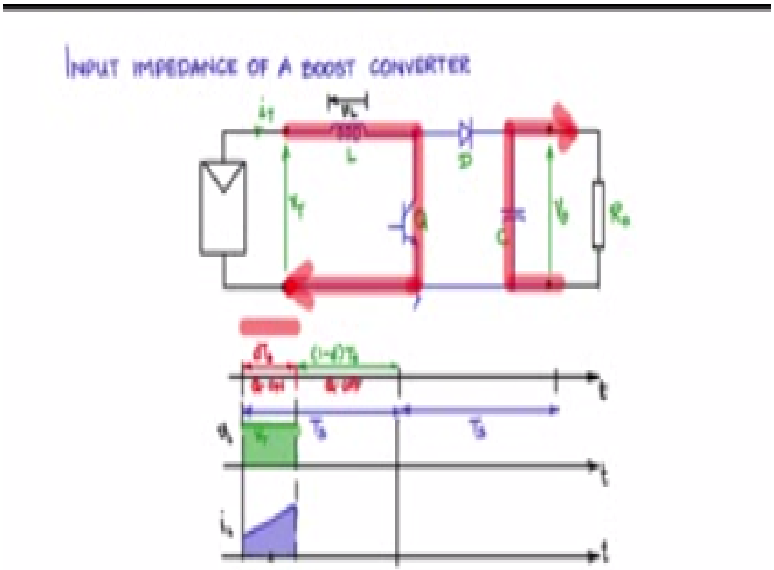

Let us see how we can use the boost converter as a power interface for MPPT consider this photovoltaic like module and this photovoltaic module is now interfaced to the load or not by a boost converter boost converter is having an inductance that is input I switch a power semiconductor switch like this now this could be a BJT as shown here or it could be an IGBT or it could be a MOSFET any of the switches any of the power semiconductor switches can be used herein switched mode on/off mode.

So this point from this Junction we need to use a diode and get to a capacitor output capacitor, so this portion forms our boost converter circuit now to the terminals at the output of the boost converter you connect the load application load like this. So let us name the parts so that is R_0 here is the terminal voltage VT the inductor L letter shape the current flowing through the terminals PV panel I T the same IDs flowing through the inductor so IL is same as I T we call the switch's q-diode T capacitor C and output voltage V.

Now let me draw our timeline T and I will mark by these ticks as shown the distance between these first two thick that is called TS the time period the switching time period so it is with respect to the power semiconductor switch Q this is the switching frequency of q1 by the switching frequency is TS period likewise this is also another TS period now the T is period itself is subdivide into two parts the switch is off and the switch is off.

So let us mark with another tick here and this period we will say is d TS d is a value less than 1 0 to 1 so DT is the time and the switch is on and obviously 1 -0 d TS will be the time when the switch is off so we will say this is the on time of qq1 and is the off time of q now consider the on time when Q is on what happens when Q is on the current flows through in this path during that time so current flows like that not only that this current flows like this the capacitor is also continuously discharging to the load.

So this is also happening the diode is off because this is at V_0 potential this Q is on so this is a ground potential of the circuit so the diode is reverse bias diode is off so you have like two separate circuits one the PV charging up the inductor like this the C the capacitor discharging to the load in this fashion. So during the time and Q is on we can observe the voltage across the inductor and the current through the inductor these are critical electrical parameters that you need to know about any converter.

So let us say you have the voltage across the inductor measured in this fashion measured with the ground common probe of Kosciusko or the multi meter from here and the positive probe of the oscilloscope here so this would be VL and that will be IL, so VL if you take when during the time and the dis on this is at 0 this is at V T so you will have VT voltage coming across during the on time and during the same time the current flowing through the inductor ZM as I T the current because this is VT is constant the current will be linearly going up because V L is equal to L di L / DT IL will integrate and you will see the current waveform flowing up like that during that time.

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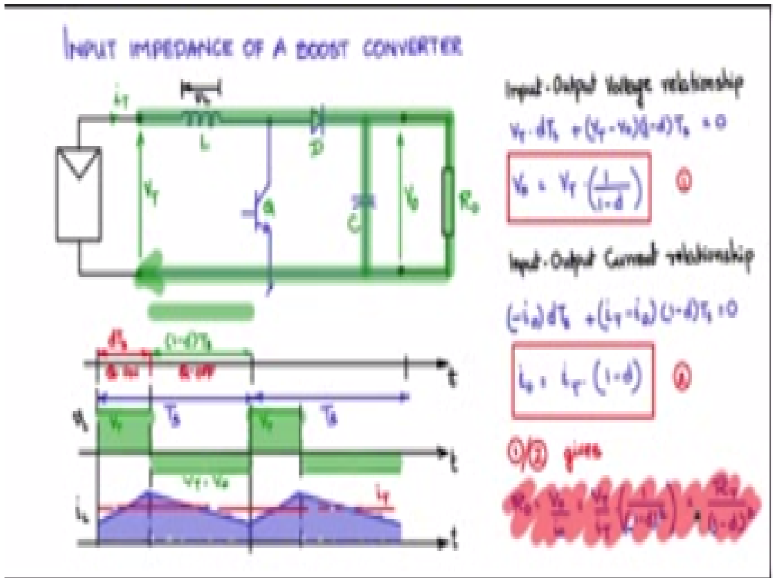

During the time when Q is off Q is off but the inductor current has to continue to flow so it will change polarity here and it will drive this diode on and charge up the capacitance and also the current will flow through the load and supply the load. So you will see that the inductor the stored magnetic charge in the inductor will discharge both through the capacitor and the load.

And charging up charges of the capacitance the voltage across the inductor now will be VT on this side on this side diode is connected to the output, so it will be V_0 so t – V_0 as V0 > VT you see that the voltage across the inductor would have gone negative and this is expected because we need the positive portion to balance out the negative portion.

So that the average voltage across the inductor is zero and the current through the inductor will DK because this is discharging now into the capacitance and discharging into the load capacitor charging up, so it will flow in this manner and then repeats every switching cycle the waveforms repeat every switching cycle in the steady state and the average inductor current the average inductor current the current that is flowing through here will be the terminal current I T let us make some space and let us try to find what is the input output voltage relationship.

The input output voltage relationship means relationship between V T and V_0 we will use property that the average voltage across the inductor should be zero cycle by cycle in the steady state. So if you see the voltage across the inductor this is the waveform it is VT positive during DTS it is VT minus V_0 negative during 1 - DTS these two areas should balance out so therefore if we write here VT DTS so the area here is VT into TDS the area here is VT – V_0.

So $VT - V_0 \times 1$ -DTS the time intercept is 1 - TDS so these two areas should add up to 0 so if you simplify that you will get $V_0 = VT \times 1 / 1- D$ now that is the voltage relationship between the output and the input output V_0 is given by VT the terminal voltage across the panel into 1 by 1 – D. Next what is the input output relationship the current relationship see for the voltage relationship we used the volt second balance.

The Volt second balance across the inductor likewise for the current we use the amps second balance of the current through the capacitor you see that just like you have the average voltage across the inductor to be zero every switching cycle the average current through the capacitor has to be zero meaning that they should not be charge buildup in the capacitor the steady state charge buildup or charge loss.

So therefore in the steady state let us say the current through the capacitance let us look at that so during the time when Q is on during DTS the diode was off current was discharging if I say positive direction of current is flowing into the capacitor to charge it up current discharging as a negative current so that is value equivalent to I_0 so $- I_0 \times$ DTS is the capacitor discharging plus during the time when Q is off the whole inductor current is flowing in this path through the diode and a portion of it charges up the capacitance and the portion of it flows through the output resistance R I_0.
So $I T - I_0$ is what is flowing through the capacitance to charge it up so as $I T - I_0 \times 1$ - DTS so the charge up and the discharge should balance out cycle by cycle so that is equal to 0 so this on simplification leads to I_0 is equal to $I T \times 1 - D$ this is the second important relationship one is the input ordered voltage relationship the other is the input output current relationship so that is 1 and this is 2.

So if you divide one by the other1 / 2 V_0 / I_0 you will get1 / 2 so dividing 1 / 2 you get the resistance relationship and that is what we are looking for so this gives R_0 is V_0 / I_0 will be R_0 and V T / IT and 1 mine 1 / 1 – D / 1 - D will become $1 / 1 - d^2$ so VT / IT VT / IT is nothing but RT has seen from the DV panel side so I will put it as RT / 1- D whole square so this is the crucial relationship that we would like to use for maximum power point tracking not let us look at this whole circuit from the viewpoint of this resistance relationship.

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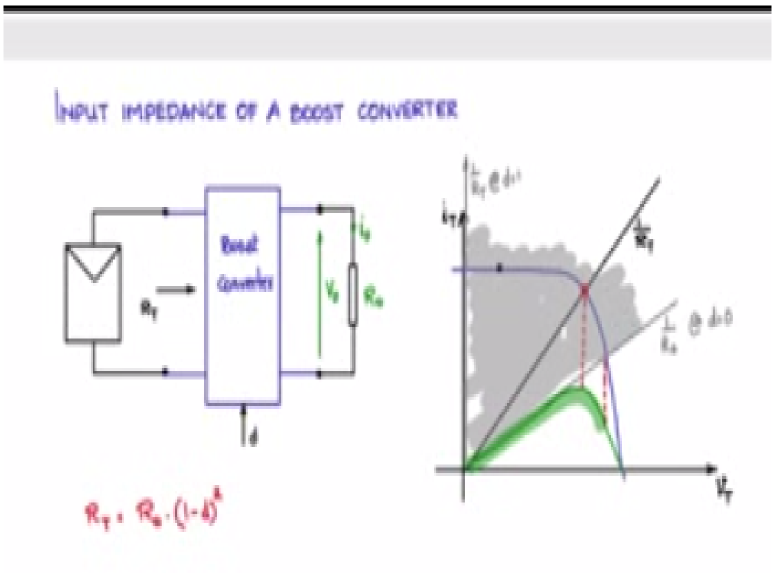

Let us now see what is the effect of the boost converter on the MVP T through the IV characteristic curve so I am replacing the boost converter by block and we have the load resistance R not like this so this is R_0 you have the voltage across the output V_0 and the current through R $_0$ as I_0 the impedance seen from the input side is RT here and the boost converter is having a control input D and we have just now seen that RT the terminal resistance on the input side of the boost converter is equal to R_0 x 1 – D^2.

So now let us draw the IV characteristic VG the terminal voltage on the x-axis this is terminal voltage VT and the current through the terminal current through the PV panel on the terminal on the y-axis that is I T so let me draw a sample IV curve and a PV curve is the IV curve and the power curve with a peak power point here and also drawing the load line 1 by RT that the panel has to see 40 Power Point operation.

So the point of intersection is operating point and the line dropping down to the power curve will give you the peak power point and is a big power operating point so let me draw another load line here what happens to R T when B is varied so if d is 1then you know that 1 - 1 RT becomes0 so when RT becomes 0 the slope becomes infinitely so it is aligned along the y axis which is going to result in an operating point which is here which is a short circuit operating point. So it is behaving when these made 0 whatever maybe the value of R_0 the load line presented to the PV panel is a vertical line which resembles a short circuit virtually a short circuit.

So let me indicate that so this is RT now this occurs at D = 1 now what happens when D = 0 so when D = 0 you see that RT = R_0 R T same as R_0, so this happens at D =0 so from this extreme load line to this another extreme load line the load line can be varied by varying T at different values of T the load line different values of load line occurs different with different slopes and they intersect at different operating points and you have different operating points coming in here and if I drop down a vertical from the limiting load line down here you will see that these are all the power points that are accessible.

So with a boost converter in the boost converter operation these are the accessible power points and these are the operating points that are reachable by the boost converter. So any of these operating point can be reached however these operating points here which I am showing right now with the mouse cursor they are not reachable by the boost converter, so it is very essential that the extreme one by R_0 load line falls in such a way that a vertical drop down the power point is on the other side that is it is on the other side of the peak it should be noted at the peak is in the reachable portion of the operating point then the boost converter has meaning and you can use it.

So to this entire portion this is called the range of the boost converter, now there can be a problem you have to be cautious and check about that.

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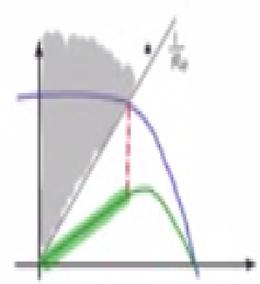

So I have here the IV characteristic with the with a limiting load line 1 / R_0 line here like this so if I put 1 / R_0 line like this then this is at duty cycle D =0 so the boost converter all the reachable points should be on the left side of that as we saw with argument just now. So if I draw a vertical from that point you will see that all these are the reachable operating points you can have the load lines of different slopes going on towards infinite slope and the power points that can be reached or these power points obviously that peak power point is not is not within the power is not within the zone of operation of the boost converter.

So it will result in an operating point which is not reachable therefore in this case the boost converter if it is used will never give you a peak power point will never give you will never be able to utilize to the fullest extent the PV module of the theory panel as the converter cannot give a load line an equivalent load line which will match the peak power point. Therefore you should be careful and check whether the boost converter can be used for a given application or not by the load line analysis first checking the limits of the load line before actually deciding on the type of the converter.